Mitigation of Capacitor Switching Inrush Current Using Air Core Reactor

Vishal V. Vashikar[1] Dr. S. Prakash[2]
[1]Research Scholar EEE Dept., BIHER, Chennai [2]Supervisor, Professor, EEE dept., BIHER, Chennai, TN, India.

Abstract

The Reactive power compensation becomes essential to the industrial sector to reduce energy bills. Due to low cost and less maintenance, air-core reactors are prevalent nowadays. The industrial sector is revised now, and lots of automation was introduced by which the load becomes nonlinear. This nonlinear behavior put more challenges in the power sector. As the energy demand increases day by day, maintaining a healthy power system becomes crucial. The capacitor banks are used for reactive power compensation. These banks operate automatically To overcome the reactive power issues. It will energize when reactive power is required. The switching of the bank produces an inrush current in the system and may cause insulation failure or burning at the consumer end. This paper introduces the air-core reactor, which suppresses the magnitude of inrush current and protects the sensitive devices at the consumer end. The design of the air-core reactor and mitigation of inrush current is discussed using MATLAB simulation.

Keywords: Air-core reactor, Capacitor switching, transient/inrush current, current limiting reactor, Power Quality

1. Introduction:

Electrical drives are not limited to a specific field; they are tremendously used in various areas. These drives have different modes of operations that create the harmonics in the power system. At multiple modes of operation of electric drives or to satisfy the load demand, these types of equipment draw maximum current from the supply. This current occurs in the system for a few milliseconds and creates disturbances in the power system operation.

The capacitor is a device which generally connected to prevent change in system voltage. The capacitor is formed by separating two conducting plates by a dielectric medium which stores the electrical energy in the form of charge. The capacitor banks are connected to fulfill the demand of reactive power of the load, but its insertion may cause the generation of inrush current. The current limiting reactors can limit this inrush current. The air-core (dry type) reactor is one of the best solutions to limit the inrush current. Here we proposed the air-core reactor module using MATLAB simulation.

2. Capacitor bank in the system:

The industrial sector consists of a nonlinear load, and a capacitor bank fulfills the reactive power requirement. For power factor improvement, capacitor banks play an essential role in the industries. These banks operate automatically. The switching operation of these banks depends on the different modes of operation of nonlinear load or

electric drives. When the reactive power injection occurs at that instant, the inrush current is observed, and its value is 4 to 5 times the rated current. It is harmful to banks and sensitive devices of the power system. The current limiting reactors are inserted in series with capacitor bank operation to limit this inrush current. The inrush current can be defined as the current drawn by the load when the capacitor bank injects the reactive power. The failure of the capacitor bank depends on the peak value of the inrush current and its duration. Therefore several parameters are to be considered while installing the capacitor bank.[1,2]

3. Current Limiting Reactor:

In AC systems, The opposition to the current flow is called the reactance. The reactor is a coil placed between two points to insert a rated impedance in the connected line to reduce inrush current. It has a high reactance value. The I^2R losses take place in the reactor. There are two types of current limiting reactors.

(A) Air-core reactor
(B) Iron core reactor

4. Air-Core (dry type) Reactor:

The air core reactors were established around 30 years ago globally, but they are used tremendously in the Indian power sector. The air-core reactor is a winding formed by a stranded wire or thin foils of aluminum or copper. It stands off on a mechanical structure to provide isolation from ground potential. The winding construction and the number of turns decide the inductance value. The number of winding turns in the air-core reactor is more significant than in the iron-core reactor. It has a more accessible isolation system and is designed by considering the RMS value of current. Its response is linear, which means its inductance does not depend on the load current. They will not be saturated During overload.

With proper insulation, we can avoid eddy current loss in mechanical structure. In the air-core reactors, the losses occur only in the winding. Its value depends on the RMS value of current. Fig. 1 shows a schematic diagram of the air-core reactor.[3]

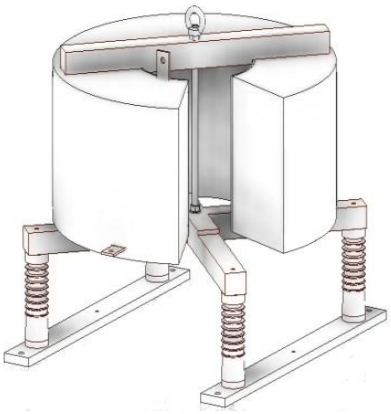

Fig.1. Air-core reactor

.

5. Case Study:

The proposed system operated with a transformer of 11kV/420V, 25MVA connected to the three-phase induction machine with the active power of 5.66 kW and reactive power of 2.7 kVAR In a MATLAB simulation module. To increase the power factor up to 0.95 capacitor bank was installed. With the installation of the capacitor bank, switching transients are produced, such as inrush current. This current may damage the capacitor bank or sensitive devices in the system.

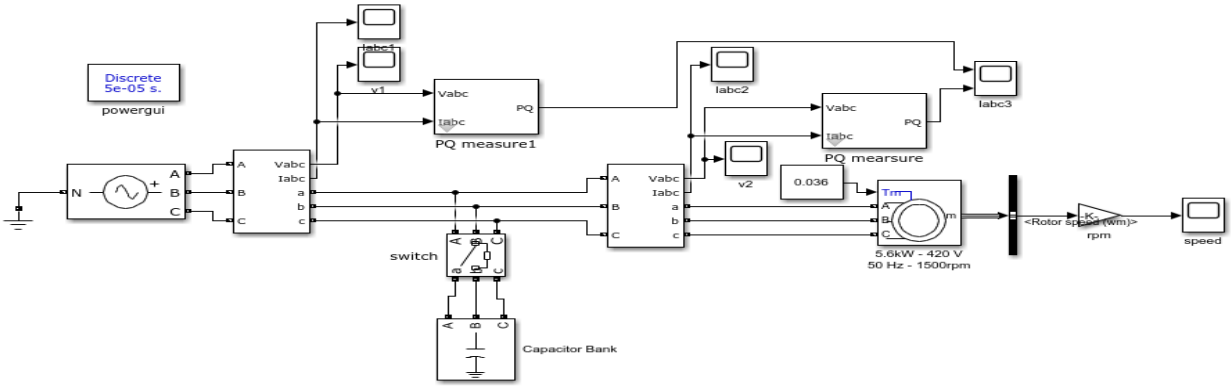

Fig.2. Simulation of the insertion of capacitor banks

Fig.2 shows the simulation of capacitor switching without an inrush current limiting reactor. To maintain the power factor, a capacitor bank is inserted. The following result was observed while switching of capacitor bank took place.

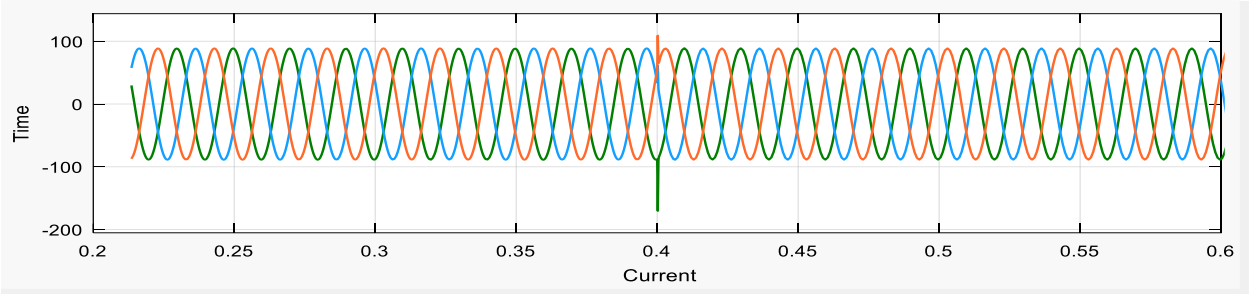

Fig.3. Simulation results of production of inrush current due to capacitor switching

The major disadvantage is it produces the inrush current, which is harmful to the capacitor bank and other nearby connected equipment. Many industrial loads are nonlinear, which aims to low power factor. The industry should pay the penalty to the electricity authority utility for low power factor. With the installation of the capacitor bank, the power factor gets improved.

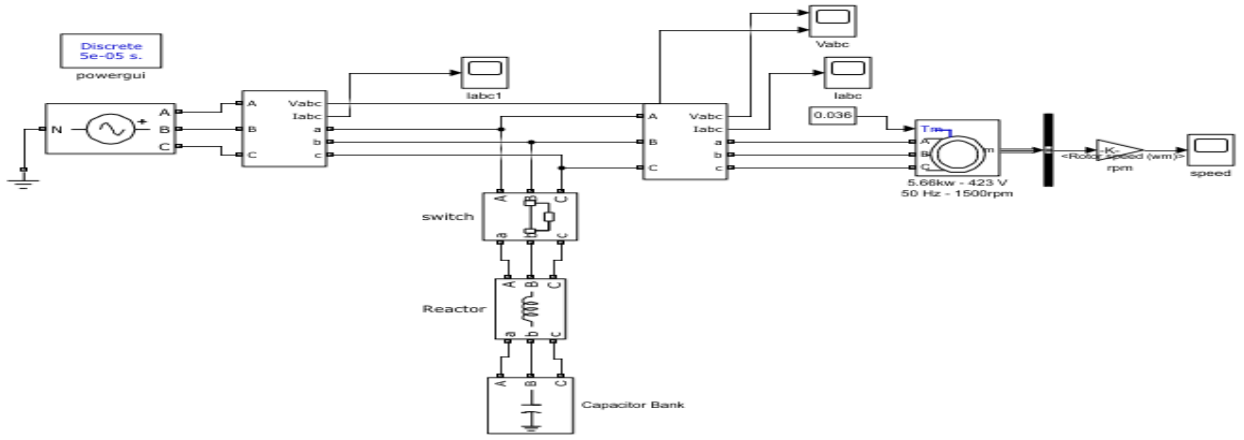

Fig.4. Simulation of the insertion of the reactor module

Fig.4 shows the Matlab simulation of the capacitor switching phenomenon with an inrush current limiting reactor. The inrush current limiting reactor reduces the switching transients of the capacitor bank and protects the capacitor bank. It also improves the reliability and efficiency of the system. The reactor has a coil with many turns, and the ohmic resistance value is much greater. The short circuit's current causes damage to the equipment of the power system. Therefore, Inrush current is limited by air-core reactors.

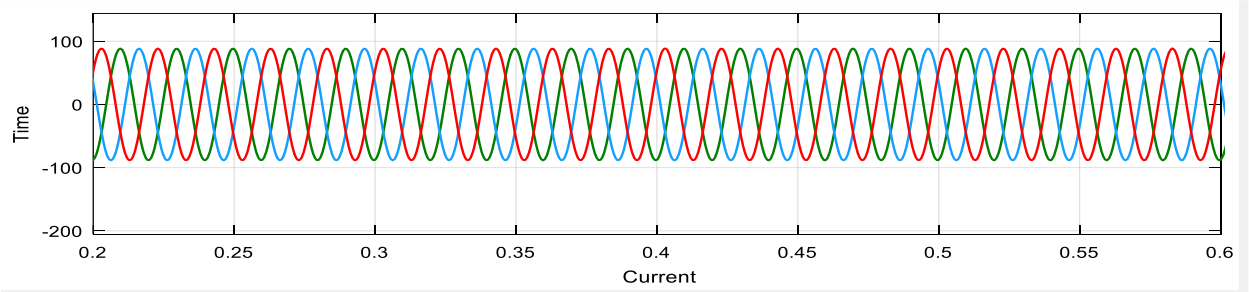

Fig.5. Simulation results of mitigation of inrush current with capacitor and air-core reactor module

Fig.5 shows the result of the reduction of inrush current using an air-core reactor. The inrush current magnitude and frequency were reduced. Also, it reduced the extent of the inrush current and gave the sinusoidal wave. It also improves the system efficiency.

Conclusion:

This paper proposes an economical and efficient way to minimize inrush current. The capacitor bank reduces power loss and improves power quality at the consumer end. During the switching operation of the capacitor bank, the generated transients are suppressed by introducing an air core reactor in series with the capacitor. The air-core reactor is one of the best solutions to control switching transients during capacitor bank switching. Meanwhile, it maintains the system's stability.

References:

[1] V.V.Vashikar, Dr.S.Prakash "Analysis of Capacitor Switching Inrush Current" Journal of Positive School Psychology 2022, Vol. 6, No. 4, 1088-1091

[2] V.V.Vashikar, Dr.S.Prakash "Protection of Capacitor Bank Against Switching Transients: An Overview," EAI DOI 10.4108/eai.7-6-2021.
[3] Dr.-Ing. Christian Kaehler, Hans von Mangoldt “Comparison Of Air-Core And Iron-Core Reactors For Medium-Voltage Power-Quality Applications” 2015
[4] M.S.Javadi, A.E. Nedzad, Pierlugi Siano and M.S.khan, "Shunt capacitor placement in radial distribution networks considering switching transient decision-making approach," Elsevier, Electrical Power and Energy Systems 92(2017)167-180.
[5] A. A. Jambukar and M. F. A. R. Satarkar, "Simulation Analysis of Switching of Shunt Capacitor Bank in 220/22 kV Substation," *2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS)*, Madurai, India, 2018, pp. 1554-1559, doi: 10.1109/ICCONS.2018.8663055.
[6] A. Dzionk and R. Małkowski, "Activity coordination of capacitor banks and power transformer controllers in order to reduce power losses in the MV grid," *2016 10th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERING)*, Bydgoszcz, Poland, 2016, pp. 27-32, doi: 10.1109/CPE.2016.7544153.
[7] J. Wang, M. Ibrahim, Z. Gajić and M. M. Saha, "Internal failure detection and protection on capacitor banks," *13th International Conference on Development in Power System Protection 2016 (DPSP)*, Edinburgh, UK, 2016, pp. 1-6, doi: 10.1049/cp.2016.0017.